Behavioral and physiological response of baleen whales to ships and ship noise

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LONG-TERM GOALS

This study began in late 2013 with the primary goal of examining the behavioral and physiological response of baleen whales to ships and ship noise off California using a combination of opportunistic and controlled research. Ship noise has been identified as the major source of anthropogenic noise in the oceans especially in areas of high vessel traffic. Ship strikes are also a growing concern especially for several species including blue and right whales that appear to be particularly susceptible. Initial research demonstrated the feasibility of documenting whale response to opportunistic close approaches of ships in areas of high levels of ship traffic particularly near known high concentrations of whales off California (McKenna et al. 2015). This juxtaposition has resulted in high levels of ship strikes (Berman-Kowalewski et al. 2010) as well as potential impacts of ship noise on blue whales (Melcon et al. 2012) and other species. In this study we continue research on behavioral response of baleen whales to ship close approaches and specifically examine how this varies with ship speed; one strategy proposed to mitigate ship strikes. We also test the response of blue whales to controlled playback of ship noise to determine the cues blue whales respond to and also to allow comparison between the response to ship noise and other anthropogenic sounds like mid-frequency sonar. To gain insight into whether ship noise and frequent passages of ships might be causing a stress response, the study includes collaboration with SWFSC to compare stress hormone levels in blue whales feeding for extended periods in areas of high ship traffic with those feeding away from shipping lanes.

OBJECTIVES

Our objectives include:

1. Determine behavioral response (avoidance and changes in dive behavior) of blue whales and other large mystecetes to exposure to close approaches by ships.

2. Examine the stimulus that appears to trigger the response to ships and whether this is a response to ship noise or the presence of the ship.
3. Examine how reaction varies with differences in ship speed and approach.
4. Determine sound exposure of a whale directly in the path of a ship.
5. Examine whether chronic exposure to ship noise causes a noticeable change in stress hormones (Kellar et al. 2006, 2009).

APPROACH

Our overall approach to achieve our objectives involves:

- Continuation of the work on reaction of whales to ships focused on increasing sample size of ships moving at different speeds and additional species of whales. Focus would include work with full speed ships in the Santa Barbara Channel (now that 1 December 2011 changes in the CARB regulations on clean burning fuel are resulting in ships returning to the shipping lanes through the Channel) and slower ships near the entrances to Los Angeles/Long Beach Harbors.
- Conduct controlled exposure experiments (CEE) using ship noise to blue whales using identical methodologies to the SOCAL BRS (Southall et al. 2012, 2013) to allow direct comparison of blue whale response to ship noise to that from other anthropogenic sources like mid-frequency sonar (MFA). Response to playback may or may not be similar to the response to close approaches of real ships being conducted opportunistically. This will also allow comparison to the response of right whales to ship noise from distant ships and playback (Nowacek et al. 2004) using somewhat similar methodologies.
- Obtain measurements of ship noise in the path of ships representing what whales at risk of a ship strike would experience using autonomous drifting recording hydrophones.
- Collect and examine stress hormone levels in biopsy samples from blue whales feeding in areas of high ship traffic such as off LA/Long Beach Harbor, especially over multiple days, compared to those from blue whales feeding farther from shipping lanes.

WORK COMPLETED

Work began on the study in mid to late 2013 so only initial project activities occurred in FY2014 and continued in 2015. Work completed to date includes:

1. Continued development and testing of tag designs to provide longer term deployments of archival tags especially for work with blue, fin, and humpback whales off California in and around shipping lanes. Modifications in tag design for 2015 included improvements in the stainless steel darts used to attach archival tags to resist breaking including modified heat treatment of darts to make them more malleable and less breakable, adding and integrating reinforcing sleeves at dart base (Figure 1).
2. Developed and tested a high sample rate accelerometer sensor to provide better dive kinematics and detect calls of whales (as described in Stimpert et al. 2015) for extended durations in conjunction with dart-attached archival tag deployments.

3. Successfully conducted 19 deployment of tags on blue, fin, humpback, and minke whales in 2015 S and central California, especially in and around shipping lanes collecting just over 900 hours of data (Table 1).
4. Worked with Southall Environmental Associates to deploy and test the J-15(3) sound source being used for playback of ship noise.
5. Conducted an initial CEE playback of ship noise on a blue whale tagged with a Dtag3.
6. Conducted a successful cruise with Channel Islands National Marine Sanctuary utilizing their vessel *Shearwater* in 2015 off southern California which included surveys of S California shipping lanes, successful deployment of archival tags, deployment of J-15(3) sound source and CEE playback of ship noise and acoustic monitoring of ships in the shipping lanes. Unfortunately low presence of blue whales due to warm temperatures limited the number of animals available for tagging and a 2nd cruise to continue playbacks was postponed to 2016.
7. Published findings related to project in Endangered Species Research titled "Simultaneous tracking of blue whales and large ships demonstrate only limited behavioral responses for avoiding collision" which summarizes research to date and follows up previous work (McKenna et al. 2011, Calambokidis et al. 2011, 2013).
8. Work has continued in collaboration with the SOCAL Behavioral Response Study (under separate funding) which provided some important information on blue whale behavior and response to ships off the LA/Long Beach area incidental to sonar testing and will also provide data on response of blue whales to Navy sonar that will serve as an important basis of comparison to controlled ship noise exposure results from this study.

Figure 1. Dart attached archival tag including TDR-10F-Fastlock GPS tag, high sample rate accelerometer unit, ARGOS transmitter, VHF transmitter along with modified stainless steel darts for medium duration attachments to whales to provide information on movements in and around shipping lanes and responses to close approach of ships.

Table 1. Summary of tag data from 19 tag deployments on blue, fin, humpback, and minke whales in 2015 related to this project. Some deployments were conducted in conjunction with work on other projects, in particular the SOCAL-Behavioral Response Study, but are only included below if they specifically provided data useful to the objectives of this study.

		Species				
Tag type	**n**	**Minke**	**Blue**	**Fin**	**Humpb.**	**Total h**
n	19	1	7	1	10	
Dtag3	3	0.5	5.8			6.2
Mk10F-dart	11		741.4	2.9	141.0	885.3
Video	4				15.9	15.9
Total h	18	0.5	747.2	2.9	156.9	907.4

RESULTS

Effort in 2015 represented the second full year of this project (Awarded in Sept 2013 with a start date of 15 August 2013). The continued successful development and testing of a dart attachment system for archival tags was put into use and increased our ability to gather longer term data on whale movements and behavior in and around ships. Dart attachments provided detailed diving and GPS data for up to 3 weeks (Table 1, Figure 1). Dart attached archival tags on blue whales provided the most hours of data totaling 741 hours from just 4 deployments of these tags (38-392 h deployment durations). Tag deployments in 2015 yielded several key findings:

1. First successful deployments of medium duration high sample rate accelerometers, gyroscope, and magnetometers (sampling at 200 Hz) on blue and humpback whales and these yielded high resolution kinematics data for more than 6 days of this almost 11 day deployment (Figure 2).
2. Above record included several thousand GPS quality positions that detailed both long range and fine scale movements (Figure 3).
3. Deepest dive recorded for a E N Pacific blue whales at 415 m. This came from a 392 h deployment off San Miguel Island in October 2015 (Figure 4).

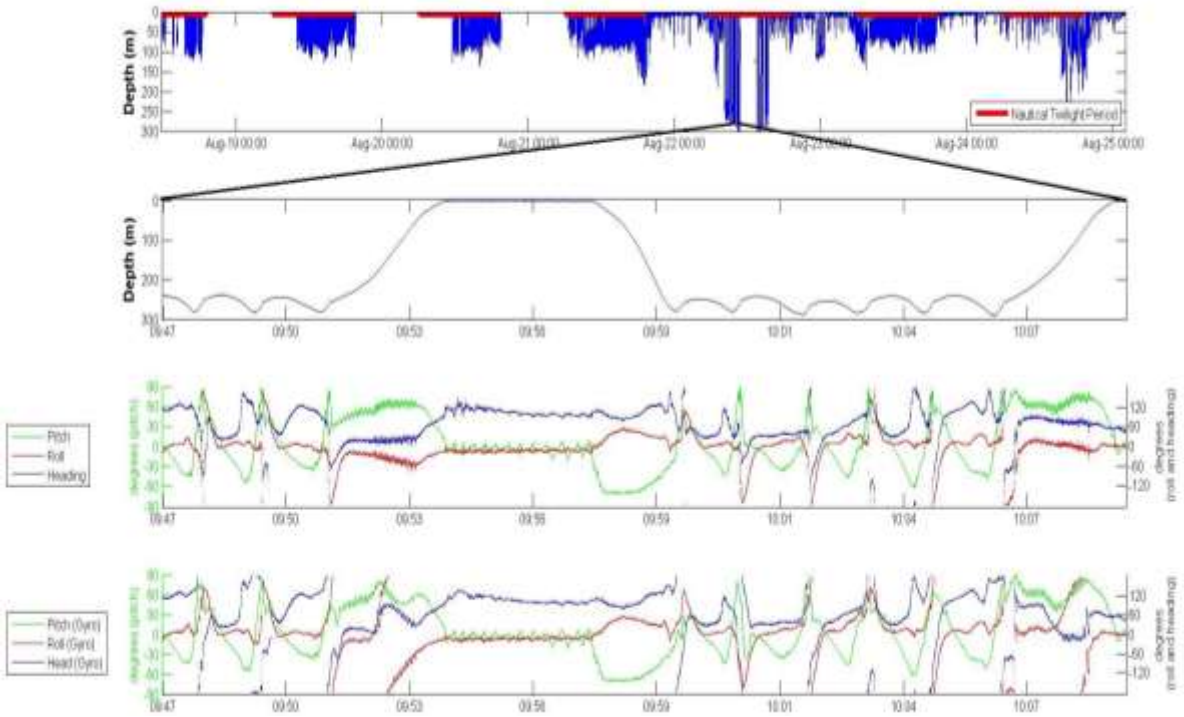

Figure 2. High resolution dive and accelerometry data first obtained in August 2015 from a blue whale deployment in the S California Bight.

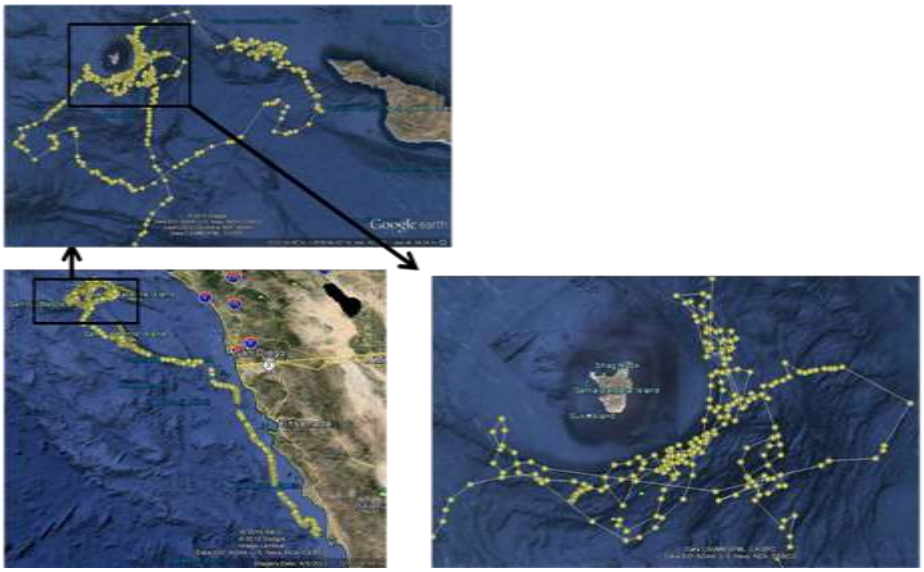

Figure 3. Movement of a blue whale 18-29 August 2015 at three different spatial scales from the broad in lower left corner, medium at top, and fine scale at lower right showing high resolution positions from fast-lock GPS.

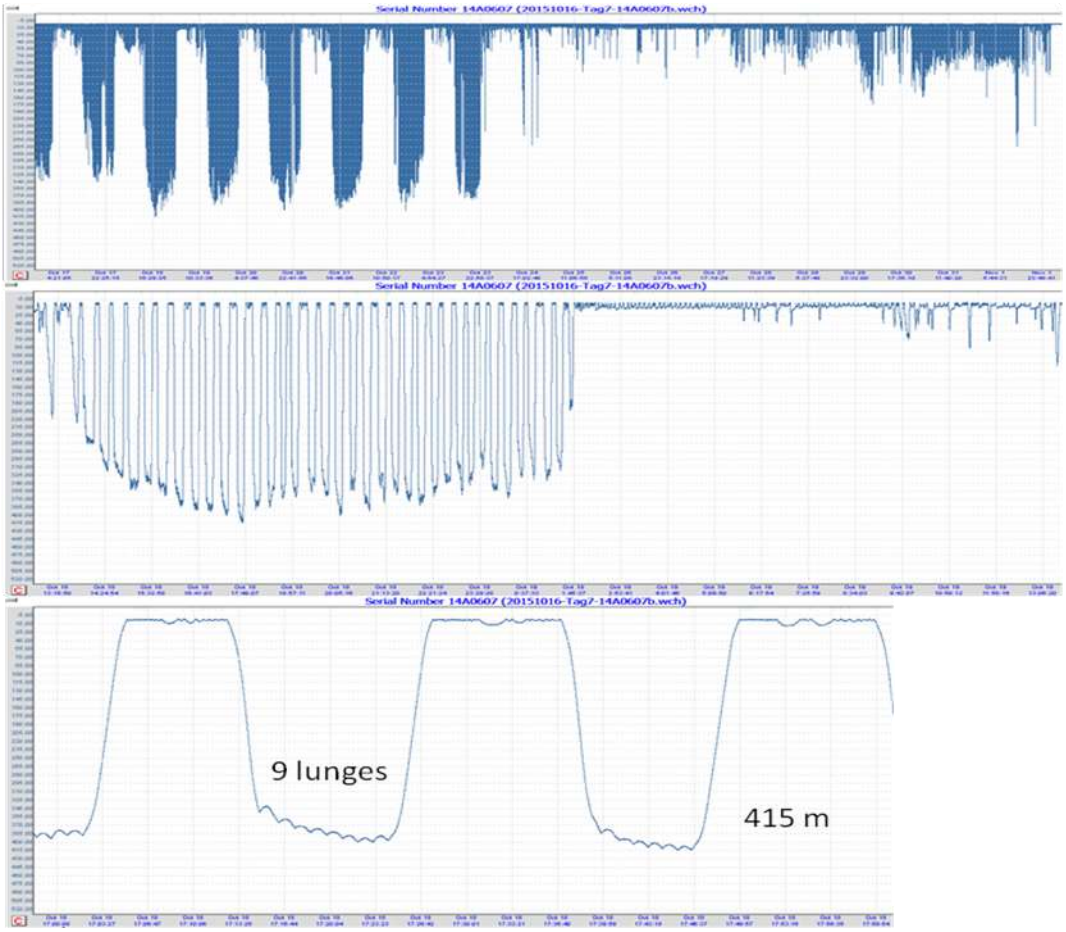

Figure 4. Dive record from 16 day deployment (16 Oct to 1 Nov 2015) on a blue whale showing full dive record (top), one day-night period (middle), and two dives showing record deep dives (415m) including one with 9 lunge events (bottom).

Initial Controlled Exposure Experiments (CEEs) with playback of ship noise from a J-15(3) were conducted in August 2015 working from the Channel Islands National Marine Sanctuary vessel *Shearwater* (Figure 5). While this initial playback experiment was successfully conducted to a blue whale with a deployed Dtag3, additional CEEs were not able to be completed due to very few blue whales being present in our main study area (related to very high water temperatures). Blue whales were scarce in the Santa Barbara Channel and around LA/Long Beach, areas frequently used in other years (Calambokidis et al. 2015). Blue whales were present west of San Miguel Island but weather conditions made it challenging to operate in that area. After the low encounters in the August 2015 field effort, we postponed a planned September field effort to the 2016 field season in the hope of having greater abundance of blue whales to provide a better chance of getting more playbacks conducted. The low density of animals in and around the shipping lanes inside the S California Bight also made it hard to conduct other tag deployments or biopsy collections of blue whales using waters in and around the shipping lanes.

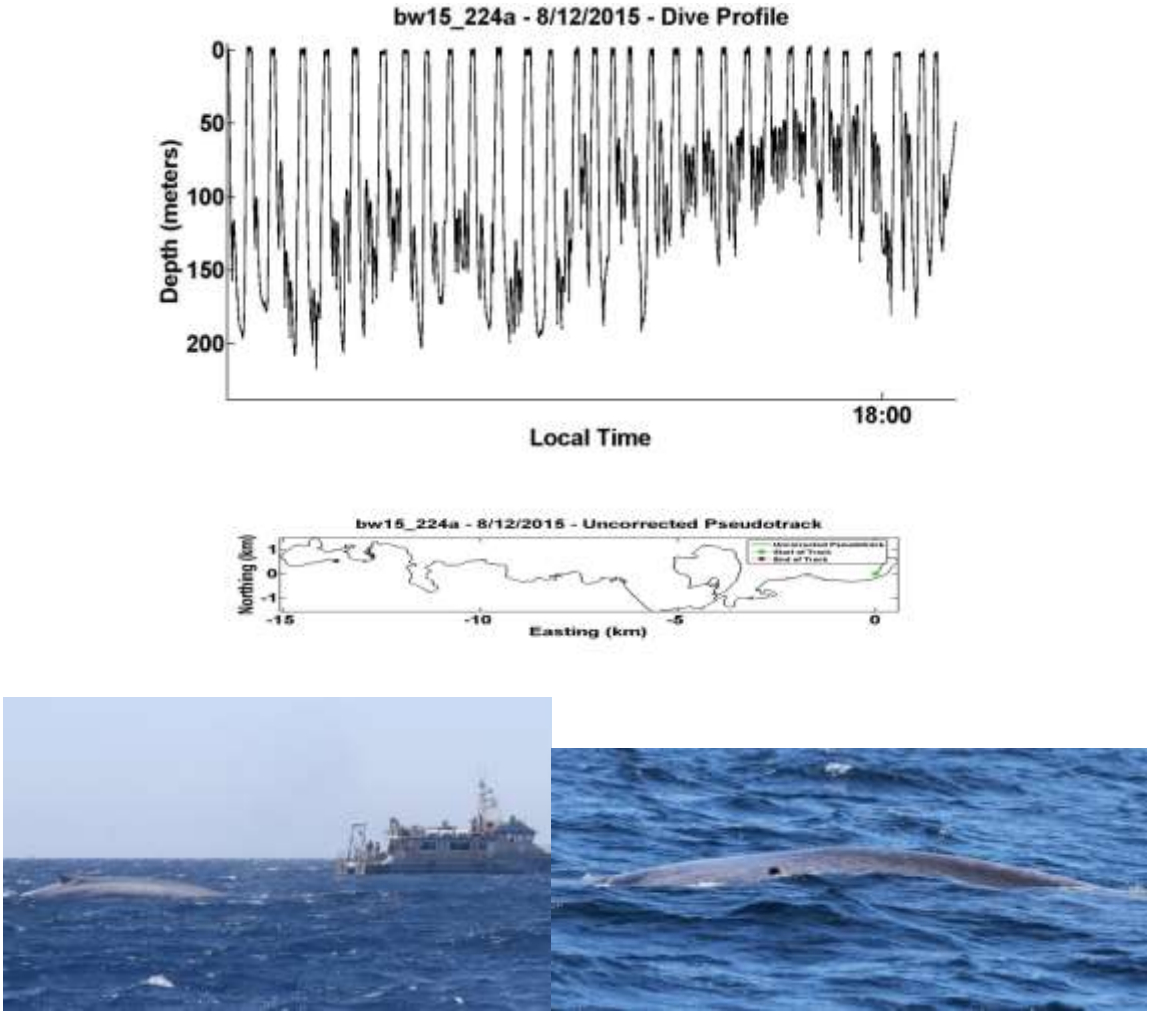

Figure 5. Dive and uncorrected track of Dtag3 deployment on a blue whale on 12 August 2015 which included the first playback of ship noise with a J-15(3) operated from the NOAA vessel Shearwater.

RELATED PROJECTS

This project is being conducted in collaboration with several other related efforts:

1. Collaborators with Dr. Nick Kellar at SWFSC who will be receiving funding from ONR for the testing of stress hormones in later stages of this project. This component while an integral part of this study is being funded separately from our award because it is going to another federal agency.
2. Field effort in 2015 was conducted in coordination with NOAA including the Channel Islands National Marine Sanctuary as a part of an ongoing project examining ship strike risk to whales off California.
3. The SOCAL Behavioral Response Study to Navy sonar (funded by the Navy's Living Marine Resources program) will serve as an important basis of comparison for results from this study and there was some cross over in data obtained (see above).

4. Acoustic data gathered on blue and fin whales will also be used for another ONR sponsored to grant to Scripps Institution of Oceanography on calling behavior of whales to aid in interpreting acoustic call detections on HARPS.

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